2006

Monitoring Of Subsidence Movements at Major Infrastructure

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MONITORING OF SUBSIDENCE MOVEMENTS AT MAJOR INFRASTRUCTURE

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ABSTRACT: Time based mine subsidence predictions provide a valuable tool, as part of an overall management strategy to protect infrastructure, which involves making subsidence predictions at set increments of longwall travel. The predictions can be presented as a series of subsidence contours or profiles, and can be animated to show the progression of the subsidence travelling wave. The observed movements at major items of infrastructure can then be compared to the predicted movements at any time throughout the mining period. The challenges in providing time based predictions are discussed. Two examples are provided: the Main Southern Railway at Tahmoor Colliery and the gas and water pipelines across an unnamed Creek at West Cliff Colliery. Both examples show that time based predictions can provide a useful tool as part of an overall management strategy where major items of infrastructure are mined beneath. Time based predictions can be readily provided for any major item of infrastructure using current methods of subsidence prediction.

INTRODCTION

Major items of infrastructure have been mined beneath, are currently being mined beneath, and are proposed to be mined beneath within the NSW Coalfields. The major items of infrastructure include freeways, major roads, railways, gas pipelines, water pipelines, electrical services and telecommunication services.

Time based mine subsidence predictions provide a valuable tool, as part of an overall management strategy to protect infrastructure, which involves making subsidence predictions at set increments of longwall travel. The predictions can be presented as a series of subsidence contours or profiles, and can be animated to show the progression of the subsidence travelling wave. The observed movements at major items of infrastructure can then be compared to the predicted movements at any time throughout the mining period.

Time based predictions can be used to provide trigger levels for management strategies when observed movements exceed predicted movements. They can also be used as a guide for the early detection of irregular subsidence movements.

ADVANCEMENTS IN TIME BASED PREDICTIONS AND MONITORING

In the past, one difficulty with providing time based predictions was the amount of calculation required to be undertaken. However, with the advancement and improvements in the accuracy of methods of prediction and the ever increasing speed of computers, time based predictions can be readily provided for any major item of infrastructure which is to be mined beneath.

There are a number of methods of predicting subsidence, including Empirical Methods, Profile Function Methods, Influence Function Methods, Numerical Modelling Methods, and Graphical Methods. To provide time based predictions, the method of prediction must be capable of determining the predicted movements at any point within the mining area, rather than just determining the maximum movements over the mining area.

One method which can be used to make time based predictions is the Incremental Profile Method, which was the method used for the examples in this paper. The Incremental Profile Method was developed by Mine Subsidence Engineering Consultants (MSEC) in the latter part of 1994, and has been continuously improved over time.

The method initially used a number of prediction lines, orientated perpendicular to the longwall panels, to make predictions of subsidence, tilt and strain across the longwalls. The predictions along each line were made based on a library of standard profiles obtained from observations at a number of collieries in the Southern, Newcastle, Hunter and Western Coalfields of New South Wales.

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At the time of this report, the library consisted of 693 different half-profile shapes for single-seam mining situations, and 236 different half-profile shapes for multi-seam mining situations. The shapes of the observed subsidence profiles vary for areas with differing geologies and, therefore, site specific predictions are undertaken where local monitoring data is available.

The prediction lines provide profiles of subsidence, tilt and strain across the longwalls, based on the local depth of cover, extracted seam thickness, geology, and longwall dimensions. The predicted subsidence, tilt and strain contours across the mining area are then determined from the profiles along the prediction lines, using a proprietary contouring program such as Surfer.

In the last two years, the Incremental Profile Method has been refined so that predictions can be made at specific points across the mining area, rather than along prediction lines, which allowed some automation of the prediction process. The method predicts subsidence, tilt and strain at any point within the mining area, based on the local depth of cover, extracted seam thickness, geology and longwall dimensions, using the same library of profile shapes.

The Incremental Profile Method can be used to make predictions on a grid of points across the mining area, which can then be used to make predicted subsidence, tilt and strain contours over the longwalls. The Incremental Profile Method can also be used to directly make predictions along the alignments of items of infrastructure.

The Incremental Profile Method has recently been transferred into C++ programming language which has dramatically increased the speed of calculation. This has allowed the prediction of subsidence contours across the mining area, and hence predictions at major items of infrastructure, to be readily determined for varying longwall extraction face positions.

Time based predictions require that subsidence contours are determined for set increments of longwall travel. The chosen increment of the extraction face is dependant on a number of factors, including maximum predicted subsidence, the sensitivity of major infrastructure to subsidence movements, and the proposed rate of mining. An increment of between 20 and 50 metres has typically been adopted in the past.

The shape of the predicted subsidence contours above the extraction face is dependant on a number of factors including the geology, mining geometry and the rate of extraction. At very slow rates of extraction, the shape of the subsidence travelling wave above the extraction face is similar to the shape above the finishing end of a longwall panel which has a similar geology and mining geometry. At faster rates of extraction, the shape of the subsidence travelling wave above the extraction face is flatter, and the resulting longitudinal travelling tilts and strains are less.

There is limited amount of observed data for longwall travelling waves for varying geologies, mining geometries and extraction rates. A conservative approach is to adopt the finishing end subsidence profile for the travelling wave at the extraction face, which provides upperbound predictions for the travelling tilts and strains. A more accurate representation would be to adopt a subsidence profile at the extraction face which has a slope of between 50 % and 90 % of the finishing end of subsidence profile, depending on the rate of extraction.

The predicted subsidence movements at the major items of infrastructure can be determined from the predicted subsidence contours over the mining area. It is possible, using the Incremental Profile Method, to make predictions directly at each item of infrastructure, rather than determining the predictions from the subsidence contours over the mining area. However, the subsidence contours over the mining area can be more easily reviewed and verified than if predictions are made directly at the major items of infrastructure.

EXAMPLES OF TIME BASED PREDICTIONS

An example of time based predictions has been made for a generic longwall layout consisting of three longwalls. The predicted subsidence contours and the predicted profiles of subsidence along the longitudinal axes of the longwalls, at four increments of the second longwall extraction face position, are provided in Figure 1. The predicted profiles of subsidence along the transverse line, at 50 metre increments of the extraction face for each longwall, are provided in Figure 2.

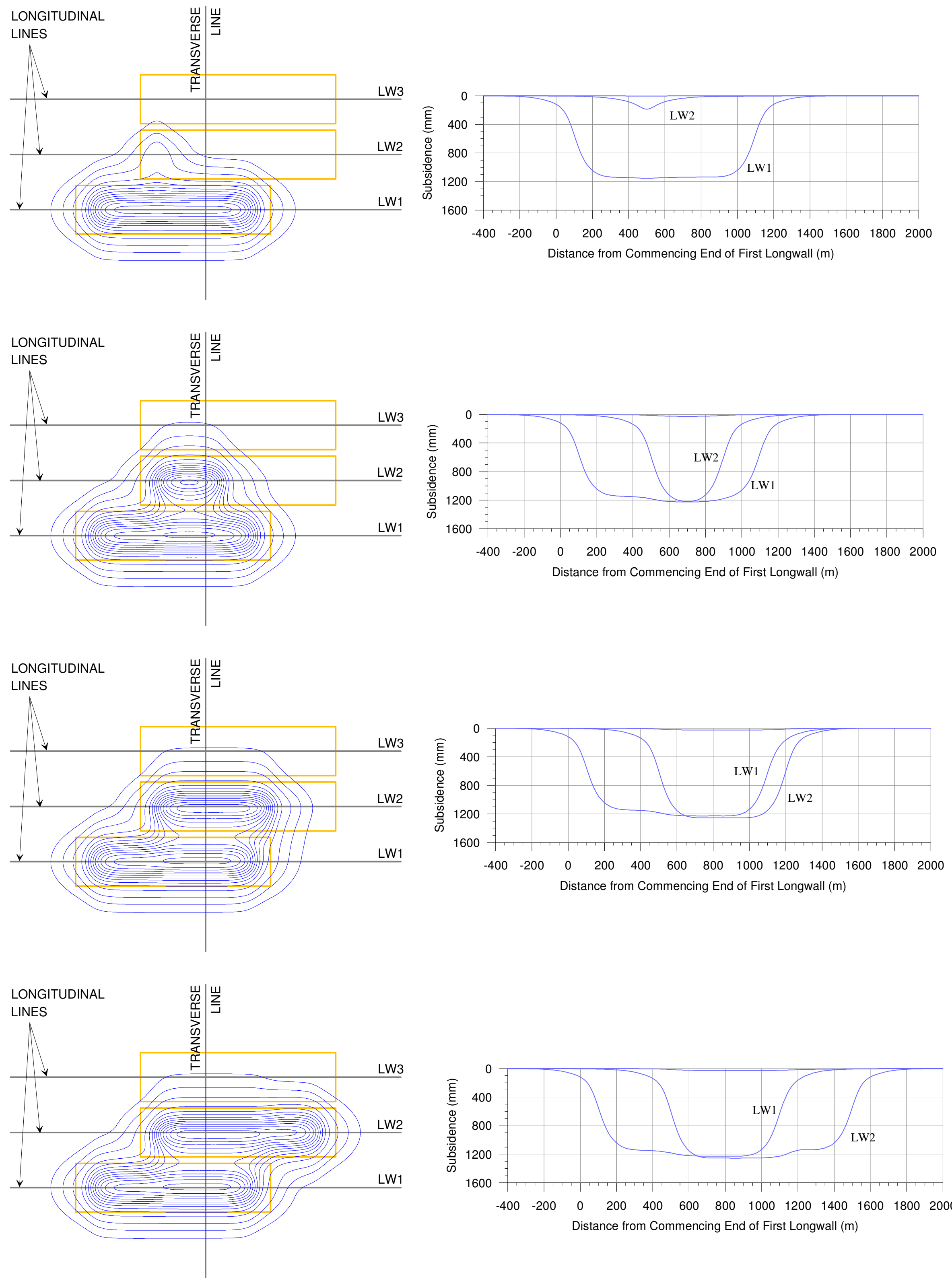

Fig. 1 - Predicted Subsidence Contours and Predicted Subsidence Profiles along the Longitudinal Axes of the Longwalls during the Extraction of the Second Longwall.
(The rectangles indicate the outline of the longwall extraction area. The thick lines that are oriented longitudinal to the longwalls indicate the location of the prediction lines for this figure. The graphs show the predicted subsidence profiles along these prediction lines.)

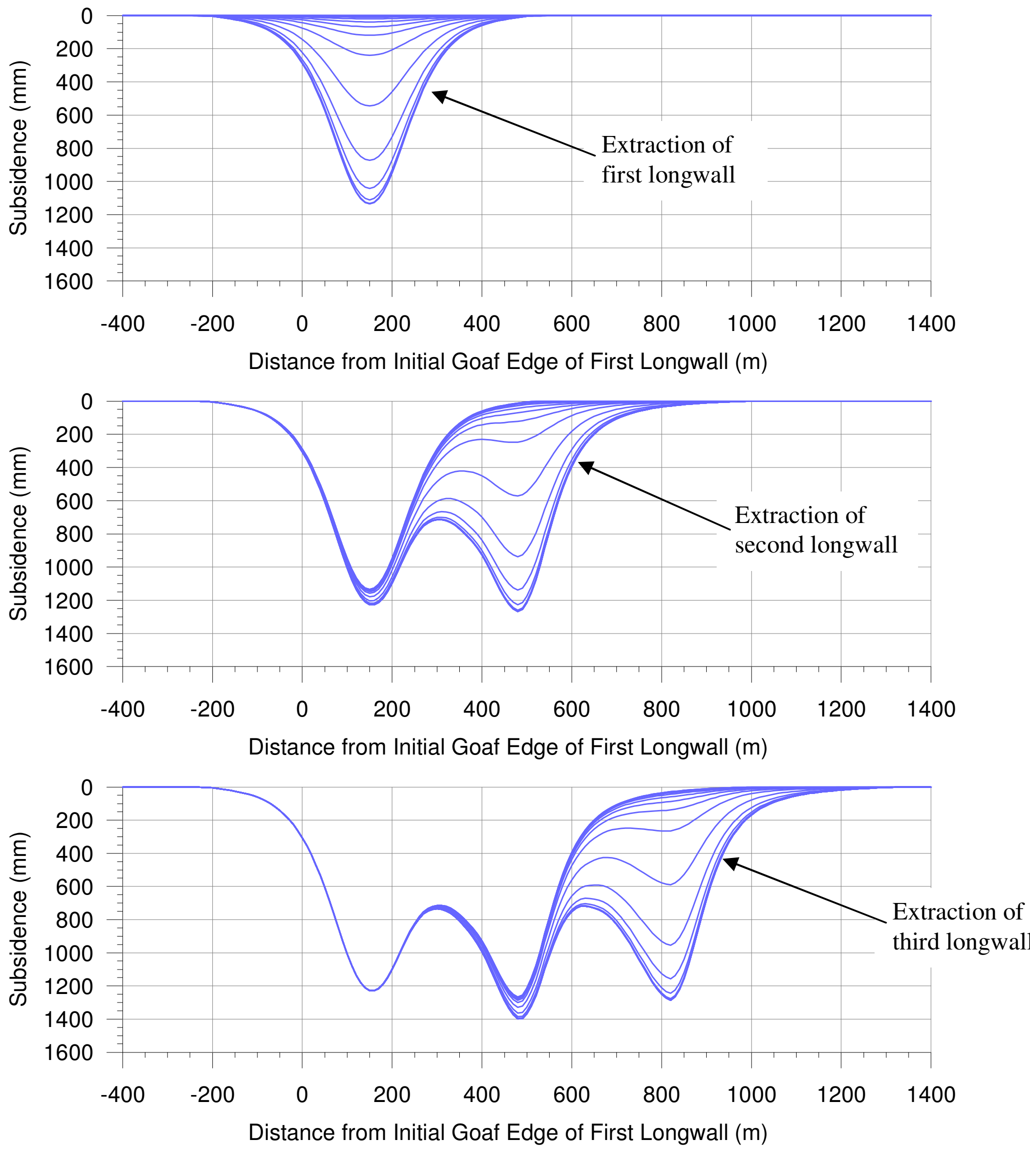

Fig. 2 - Predicted Subsidence Profiles along the Transverse Line
(The transverse line is indicated in Fig 1 as a vertical thick line)

The predicted subsidence contours and the predicted profiles of subsidence along the transverse and longitudinal lines show the progressive development of subsidence during extraction of the longwalls.

APPLICATION OF TIME BASED PREDICTIONS

Time based predictions have been made at a number of major items of infrastructure in the past. Two examples are provided in this paper: the Main Southern Railway at Tahmoor Colliery and the gas and water pipelines across an unnamed Creek at West Cliff Colliery.

An early use of time based predictions was made in 1998 for the Cataract Tunnel at Appin Colliery. It was originally intended that predictions were to be made for 50 metre increments of the longwall extraction face; however, this was reduced to a total of six increments due to the amount of calculation involved. With current methods of prediction, however, the 50 metre increments can be calculated in less time than the six increments took in 1998.

The Main Southern Railway is located adjacent to Longwall 23A at Tahmoor Colliery. The location of the railway and the longwalls at Tahmoor Colliery are shown in Figure 3. The Incremental Profile Method was used to determine the predicted incremental subsidence contours, due to the extraction of Longwall 23A, at 50 metre increments of the extraction face position. The actual subsidence along the railway was monitored during the extraction of this longwall, and a comparison between the maximum observed subsidence and maximum predicted subsidence along the railway is provided in Figure 4.

Fig. 3 - Location of Longwall 23A and the Main Southern Railway at Tahmoor Colliery

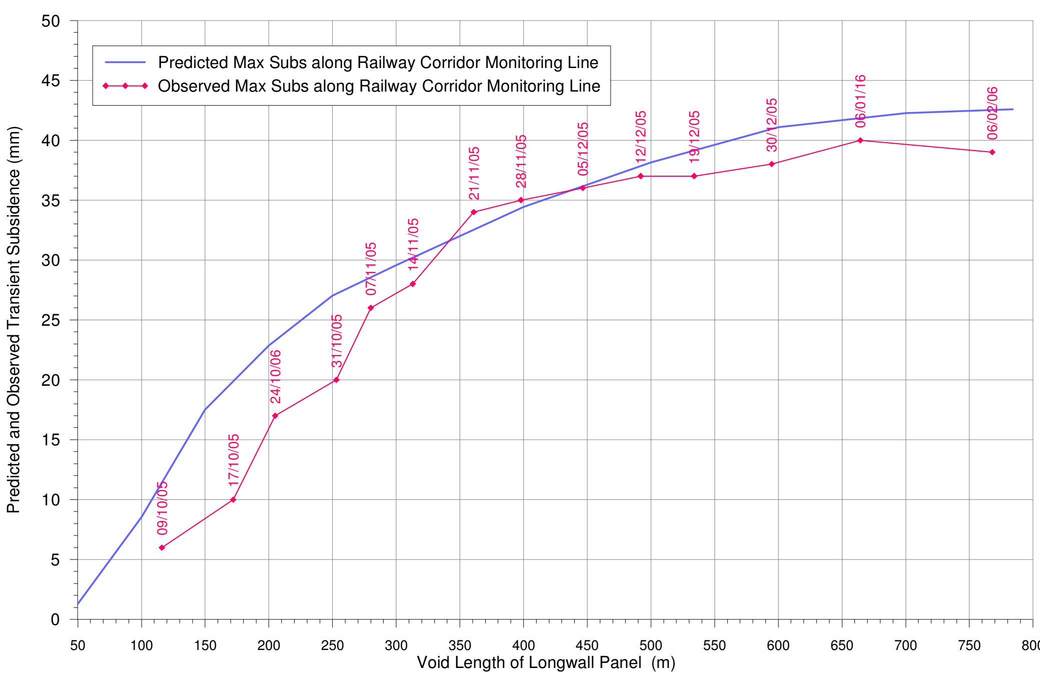

Fig. 4 - Comparisons between maximum predicted and maximum observed subsidence movements along the Main Southern Railway due to Tahmoor Longwall 23A

It can be seen from the previous figure that the observed movements were generally less than those predicted during the extraction of Longwall 23A. The observed movements only exceeded the predicted movements at one small moment in time by less than 3 mm, which is extremely small, and the maximum observed subsidence was less than the maximum predicted subsidence at the completion of mining.

Three natural gas pipelines and one water pipeline were mined beneath by Longwall 30 at West Cliff Colliery. The pipelines were subjected to both systematic subsidence movements, and to valley related upsidence and closure movements, where the pipelines cross Unnamed Creek. The locations of the Longwall 30, the pipeline easement and Unnamed Creek are shown in Figure 5.

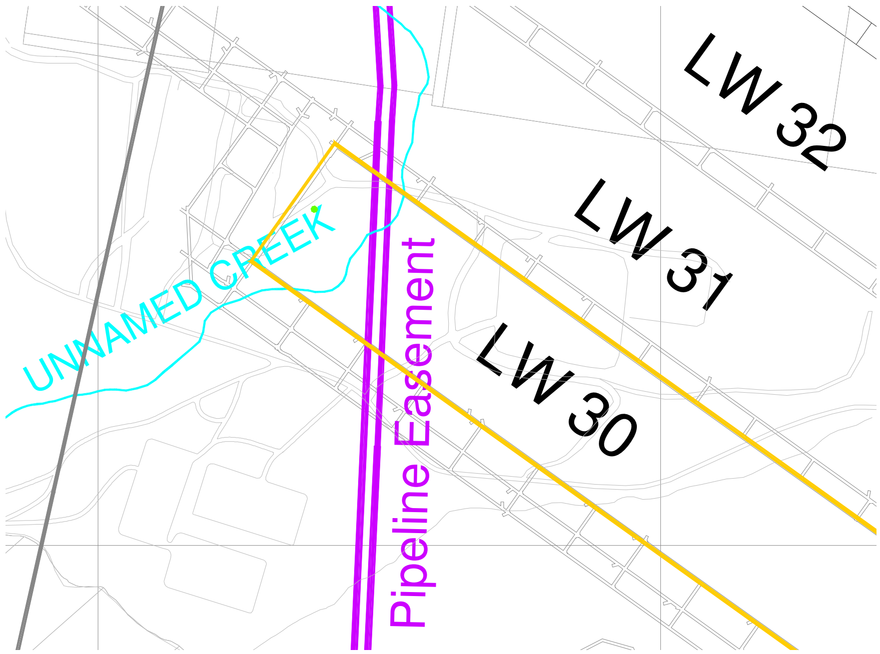

Fig. 5 - Locations of Longwall 30, the pipeline easement and unnamed creek at West Cliff Colliery

The maximum predicted subsidence, upsidence and closure along the pipeline easement were determined for increments of Longwall 30 extraction face position. A comparison between the maximum predicted and maximum observed subsidence, upsidence and closure movements along the easement, during the extraction of Longwall 30, are provided in Figure 6, Figure 7 and Figure 8, respectively.

The observed subsidence, upsidence and closure movements were generally less than the predicted movements during the extraction of Longwall 30. The observed subsidence and closure movements were initially slightly greater than predicted, however, the movements at this stage of mining were very small and naturally more difficult to predict.

It can be seen from the examples in this paper that time based predictions can provide a useful tool as part of the overall management strategy where major items of infrastructure are mined beneath. Time based predictions can be readily provided for any major item of infrastructure using current methods of subsidence prediction.

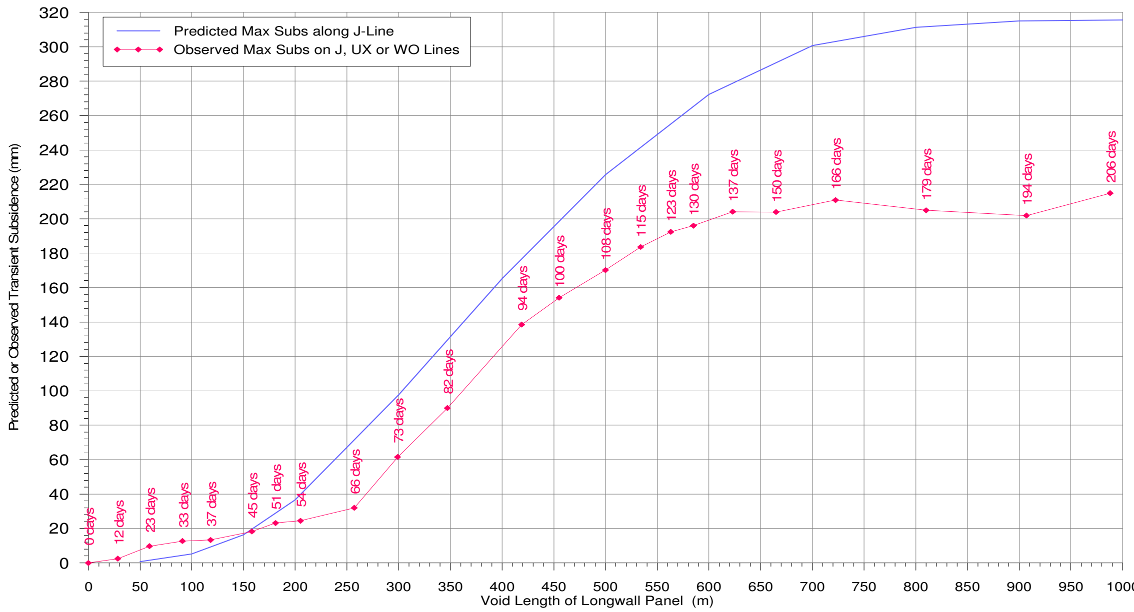

Fig. 6 - Comparisons between maximum predicted and maximum observed subsidence Movements along the pipeline easement above Longwall 30 at West Cliff Colliery

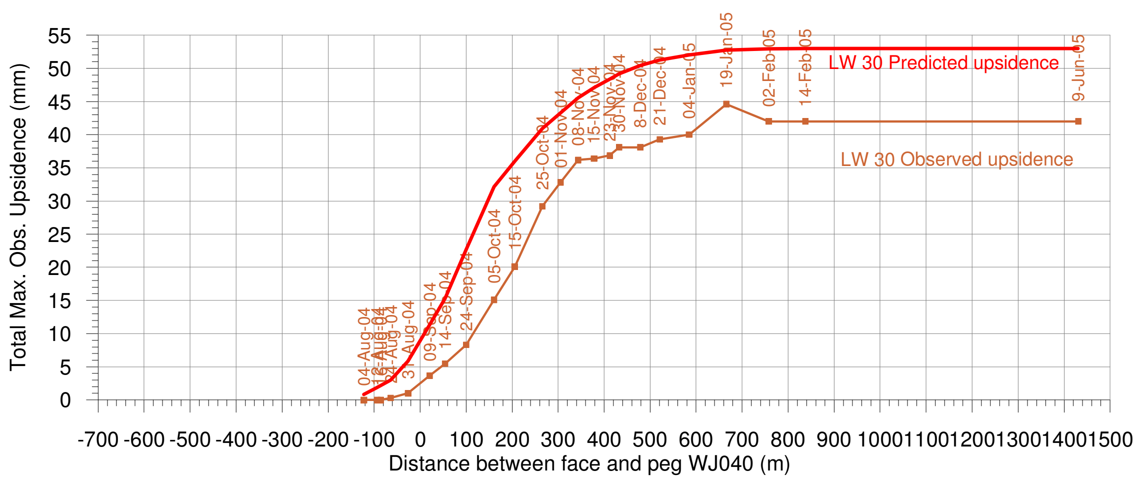

Fig. 7 - Comparisons between maximum predicted and maximum observed upsidence Movements along the pipeline easement above longwall 30 at West Cliff Colliery

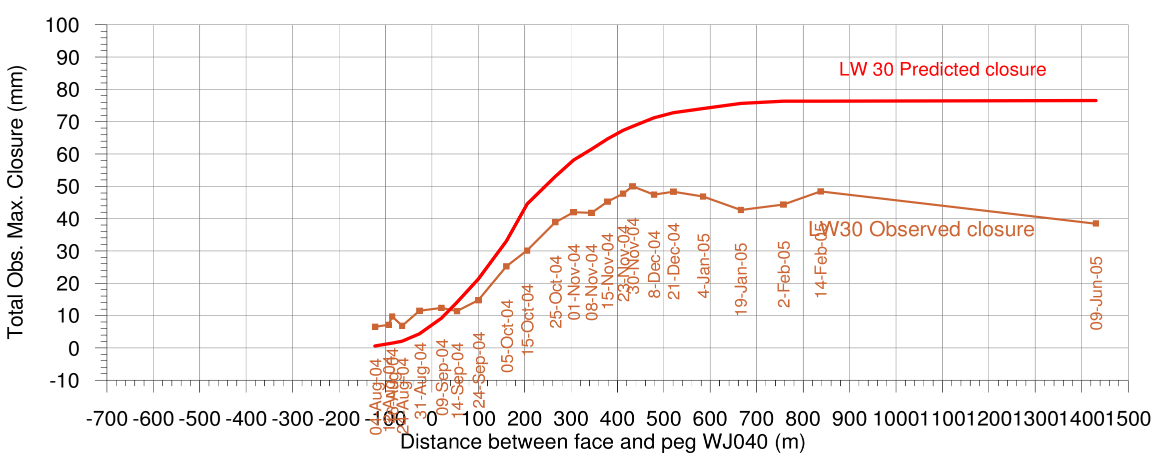

Fig. 8 - Comparisons between Maximum predicted and maximum observed closure movements along the pipeline easement above Longwall 30 at West Cliff Colliery

ACKNOWLEDGEMENTS

The authors of this paper would like to thank Illawarra Coal and Centennial Coal Tahmoor for providing information relating to mining under pipelines and railways.

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